Designation: F3057 – 14

Standard Test Method for Electromagnetic Shielding Effectiveness of Glazings[1]

This standard is issued under the fixed designation F3057; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the electromagnetic shielding effectiveness of glazings or glazing configurations.

1.1.1 The intended application of this test method is for glazings or glazing configurations to be evaluated for their transmittance or shielding capability to electromagnetic frequencies.

1.1.2 This is a component test. It is not applicable to full systems such as walls, floors, ceilings, shielded racks, or window systems.

1.1.3 The intention of this test method is to standardize a measurement procedure for glazings or glazing configurations, with and without coatings, films, interlayers, or other enhancements, as single or insulating units at a standard size and when mounted in a standardized frame.

1.1.4 This test method is to provide a means of generating data for the glazing or glazing configuration infills that can be used by the consumer, designer, and system manufacturer to understand the capability and contribution of glazings or glazing configurations to a system used for Electromagnetic Interference (EMI) security.

1.2 This test method is for use in the assessment of EMI transmittance for frequency ranges 100 kHz to 20 GHz. Specific test frequencies within these ranges are required.

1.3 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Some specific hazards statements are given in Section 8 on Hazards.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E631 Terminology of Building Constructions

2.2 *IEEE Standards:*[3]

IEEE Standard 299–1977 IEEE Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures

IEEE STD C95.1–1991 IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz

2.3 *OSHA Standard:*[4]

OSHA Regulation, 29 CFR 1910 Department of Labor, July 1992

2.4 *ANSI Standard:*[5]

ANSI/NCSL Z540.3 Requirements for the Calibration of Measuring and Test Equipment

2.5 *ISO Standard:*[6]

ISO/IEC 17025:2005 General Requirements for the Competence of Testing and Calibration Laboratories

3. Terminology

3.1 *Definitions:*

3.1.1 *accredited independent testing laboratory*—testing laboratory accredited to perform the referenced testing procedures by a nationally recognized accrediting agency in accordance with ISO/IEC 17025 and led by a test director.

3.1.2 *electric field measurements*—the attenuation provided by a glazing or glazing configuration is assessed by using a local source to generate the electric field. The electric field measurement will be from 1 to 100 MHz.

[1] This test method is under the jurisdiction of ASTM Committee F12 on Security Systems and Equipment and is the direct responsibility of Subcommittee F12.10 on Systems Products and Services.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., Piscataway, NJ 08854, http://www.ieee.org.

[4] Available from Occupational Safety and Health Administration (OSHA), 200 Constitution Ave., Washington, DC 20210, http://www.osha.gov.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[6] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

3.1.3 *magnetic field measurements*—the attenuation provided by a glazing or glazing configuration is assessed by using a local source to generate the near field. The magnetic field measurements will be conducted from 100 kHz to 20 MHz.

3.1.4 *plane wave measurements*—the attenuation provided by a glazing or glazing configuration is assessed by using a locally generated distant source or plane wave field. The plane wave measurements will be from 100 MHz to 20 GHz.

3.2 *Acronyms:*

3.2.1 *ANSI*—American National Standards Institute.

3.2.2 *cw*—continuous wave.

3.2.3 *EMI*—Electromagnetic Interference.

3.2.4 *h*—hours.

3.2.5 *IEC*—International Electrotechnical Commission.

3.2.6 *ISO*—International Organization for Standardization.

3.2.7 *NCSL*—National Conference of Standards Laboratories.

3.2.8 *OSHA*—Occupational Safety and Health Administration.

3.2.9 *pw*—plane wave.

3.2.10 *SE*—shielding effectiveness.

3.2.11 *SI*—système International d'unités (International System of Units)

4. Summary of Test Method

4.1 This section is a summary of Section 13. Specific details are included in that section.

4.2 The test method applies to the magnetic field, electric field, and plane wave, and is comprised of a reference run and a specimen run.

4.3 Measurements shall be taken at a minimum of 461 frequencies equally spaced across the tested logarithmic scale.

4.4 Reference runs are performed through the test aperture with the antenna in position but without the test specimen installed.

4.5 Specimen runs are performed in the same manner as the reference run, but with the specimen installed.

4.6 All test points are evaluated with the maximum received signal strength results stored under the specimen indicator number.

4.7 The attenuation level provided by the glazing or glazing configuration specimen is determined by subtracting the specimen run data from the reference data.

4.8 Three identical specimens are tested with the results at each test point frequency averaged.

5. Significance and Use

5.1 This test method provides measurement procedures for determining the electromagnetic shielding effectiveness of glazings and glazing configurations as a material. This test method specifies a method for comparing the glazings and glazing configurations as an infill component to allow comparison of between different infills. In addition, this test method is written to minimize variations in measured shielding effectiveness at a given frequency and test point regardless of test personnel, equipment, and test site. Therefore, the shielding effectiveness of a glazing or glazing configuration from any supplier can be determined. This test method specifies a minimum set of measurements over a frequency range to determine shielding effectiveness.

5.2 *Source Fields*—Performance of a shielded enclosure and glazing or glazing configurations are to be assessed for three source fields: magnetic, electric, and plane wave.

6. Interferences

6.1 *Interference with Electronic Equipment*—Care shall be taken to avoid interference with other electronic equipment operating in the vicinity

6.2 *Operational Impact Analysis and Risk*—The electromagnetic barrier must remain intact during the shielding effectiveness measurement sequence, and use of electrically noisy equipment must be restricted. Radiated signal levels should present no hazard to equipment, but frequency adjustments may be required to avoid self interference or interference with nearby facilities. Record the actual test frequencies. Normal electrical safety precautions apply.

6.3 The test director shall ensure that testing is conducted with inboard and outboard surfaces of the test specimen identified, and the test specimen shall be at the prescribed temperature in Section 12.

7. Apparatus

7.1 *Test Chamber*—An RF shielded enclosure that meets IEEE STD 299-1997.

7.2 *Mounting Frame*—The mounting frame must be capable of securely holding the glazing or glazing configuration in a fixed location where the glazing or glazing configuration surface is parallel to the frame. The geometrical center of the glazing or glazing configuration shall be 1 m from the floor. The edge capture of the glazing or glazing configuration shall be 26 ± 2 mm, leaving an aperture opening of 0.86 by 0.86 m ± 2 mm with the ability to test glazing configurations from 6 to 130 mm ± 2 mm thick.

7.2.1 The specimen must be mounted in the frame using standard glazing or glazing configuration installation procedures.

7.3 The mounting plates should be constructed to not exert unnecessary pressure on the glazing or glazing configuration so as to cause breakage, distortion, or compression of the glazing or glazing components.

7.4 Test equipment should be selected to provide a dynamic range that exceeds the shielding effectiveness of the glazing or glazing configuration specimen.

8. Hazards

8.1 For human exposure to electromagnetic energy in controlled environments, the maximum permissible exposure to electric and magnetic field strengths shall be minimized to the maximum extent possible. Acceptable levels can be found in IEEE STD C95.1-1991 and OSHA Regulation, 29, CFR.

9. Sampling, Test Specimens, and Test Units

9.1 *Sample*—A sample shall consist of three identical glazing or glazing configuration unit specimens. The average of the performance at each frequency is to be reported. If one specimen is not statistically valid with the other two specimen results, it may be rejected and another identical specimen tested in its place. If statistical validation for the sample set does not occur on this retest, then the results from all four specimens must be averaged and presented as the nominal performance curve for the sample.

9.2 *Specimen:*

9.2.1 *Specimen Size*—The specimen size shall be 0.91 by 0.91 m ± 3 mm.

9.2.2 *Specimen Configuration*—The specimen shall be constructed with the same materials as will be made commercially available. The materials used in the construction shall be documented. Substitution of materials or components without testing is not permitted.

10. Preparation of Apparatus

10.1 *Glazing Testing*—Testing of glazing or glazing configuration can be conducted wherever the equipment and environment are appropriate.

10.2 *Movable Equipment*—Movable equipment containing metal shall be removed from the test enclosure prior to making measurements.

10.3 *Preliminary Procedures*—Perform the following preliminary test on all accessible shielding faces to detect weak points and to permit remedy of shielding defects caused by faulty assembly and poor workmanship prior to actual measurement.

10.3.1 With the transmitting antenna turned off, perform a continuous wave (cw) measurement at each frequency to be used for testing to ensure that no emitters are nearby that may cause interference. Frequency adjustments may be necessary to avoid interferences.

10.3.2 Additionally, perform a receiving equipment coupling measurement. The setup for this measurement is the reference measurement with the following exceptions. Disconnect the receiving antenna from the nearest cable and replace the receiving antenna with a dummy load (resistive load matched to the characteristic impedance of the receiving system). Measured levels shall be negligible so the required dynamic ranges are maintained. If the measured levels are larger than expected, determine the penetration points and correct the identified leakage points. Repeat the receiving equipment coupling measurements until negligible levels are maintained.

10.3.3 Perform a noise measurement with the following equipment setup. Place the receiving antenna and equipment on the inboard side of the glazing or glazing configuration and turn off the transmitting antenna placed outboard side of the glazing or glazing configuration. The receiving antenna or the specimen can be reversed as appropriate if the specimen is asymmetrical and the orientation may cause a shielding difference side to side. The prescribed background tests are to be completed whenever the specimen or equipment is moved. Measure the noise level at each frequency to be used for testing.

10.4 After noise levels have been found negligible (or the test equipment has been modified to make the penetration negligible), position the transmitting and receiving antennas so that they align with the geometric center of the glazing or glazing configuration specimen ±6 mm.

11. Test Equipment Calibration

11.1 All test equipment shall be calibrated according to ANSI/NCSL Z540.3.

12. Conditioning

12.1 Glazing or glazing configuration shall be conditioned to 21 ± 3°C with free flowing air between the lites for a minimum of 4 h prior to test. This temperature is to be held throughout the test.

13. Procedure

13.1 *General Test Procedures for Each Glazing or Glazing Configuration Specimen:*

13.1.1 The test procedure applies to magnetic field, electric field, and plane wave and is comprised of two basic setups: a reference run and a specimen run.

13.1.2 Transmit and receive antennae must be positioned at the distances discussed above and centered (horizontally and vertically) in the aperture.

13.1.3 The reference run is performed through the test aperture with the antenna in position but without the test specimen installed. It is important that all mounting frame or bracing be installed, without the glazing or glazing configuration specimen. All test points are evaluated with the maximum received signal strength results stored as reference.

13.1.4 The specimen run is performed in the same manner as the reference run, but with the glazing or glazing configuration specimen installed. All test points are evaluated with the maximum received signal strength results stored under the specimen indicator number.

13.1.5 The attenuation level provided by the glazing or glazing configuration specimen is determined by subtracting the specimen run data from the reference data.

13.1.6 Three identical specimens are to be tested with the results at each test point frequency averaged. If the one specimen results are significantly anomalous from the other two, a new third specimen may be tested. If the new specimen is also anomalous, then the results from all four specimens must be averaged and presented as the nominal performance curve for the sample.

NOTE 1—For specific applications, the frequency range may be extended to 40 GHz. Appendix X1 provides guidance on measurement frequencies.

13.2 *Magnetic Field Testing Procedures:*

13.2.1 The magnetic field testing shall be run with the transmitting and receiving antenna located directly opposite each other and separated from the material under test by a

distance of 30.48 cm from the surface of the glazing or glazing configuration system being evaluated to the center of the antenna loop.

13.2.2 Measurements shall be made with the loop antenna oriented in three orthogonal planes with respect to the test specimen as shown in Fig. 1 below.

13.2.3 Results shall be provided at each test frequency resulting in the maximum signal strength recovered (lowest attenuation) from the three orthogonal planes test data.

13.2.4 Measurements shall be taken at a minimum of 461 frequencies equally spaced across logarithmic scale from 100 KHz to 20 MHz.

13.3 *Electric Field Testing Procedures:*

13.3.1 The electric field testing shall be run with the transmitting and receiving antenna located directly opposite each other and separated from the material under test by a distance of 183 cm from the surface of the glazing or glazing configuration system being evaluated to the center of the antenna (for dipoles and monopoles) or to the closest extremity for log-periodic and similar directional antennas.

13.3.2 Measurements shall be made with the antenna oriented (that is, rotated and directed) for optimum polarization and direction to achieve maximum signal strength with respect to the test specimen as shown in Figs. 2 and 3 below.

13.3.3 Results shall be provided at each test frequency resulting in the maximum signal strength recovered (lowest attenuation) from the two polarization planes test data.

13.3.4 Measurements shall be taken at a minimum of 461 frequencies equally spaced across the logarithmic scale from 1 to 100 MHz.

13.4 *Plane Wave Testing Procedures:*

13.4.1 The plane wave testing shall be run with the transmitting and receiving antenna located directly opposite each other and separated from the material under test by a distance of 183 cm from the surface of the glazing or glazing configuration system being evaluated to the center of the antenna (for dipoles and monopoles) or to the closest extremity for log-periodic and similar direction antennas.

13.4.2 Measurements shall be made with the antenna oriented (that is, rotated and directed) for optimum polarization and direction to achieve maximum signal strength with respect to the test specimen as shown in Figs. 4 and 5 below.

13.4.3 Results shall be provided at each test frequency resulting in the maximum signal strength recovered (lowest attenuation) from the two polarization planes test data.

13.4.4 Measurements shall be taken at a minimum of 461 frequencies equally spaced across the logarithmic scale from 100 to 20 000 MHz.

14. Calculation or Interpretation of Results

14.1 The end result must be a semi-log plot with frequency on the log scale and attenuation on the linear scale. All raw data tables and plots shall be provided.

14.2 The fields penetrating a shielded enclosure arise from both electric and magnetic components of the electromagnetic field. The results obtained must be in units of decibels.

15. Report

15.1 A technical report on the performed measurements shall be prepared. Contents of the report shall be adequate to ascertain the glazing or glazing configuration and details on the measurements to assure the validity of the approach and accuracy of the instrumentation. In addition to a title page, required report content is described in the following subsections.

15.2 *Background*—This section of the report will normally address the following:

(1) For whom the report was prepared and by whom.

(2) Name, model, serial number, and description of the shielded enclosure under test,

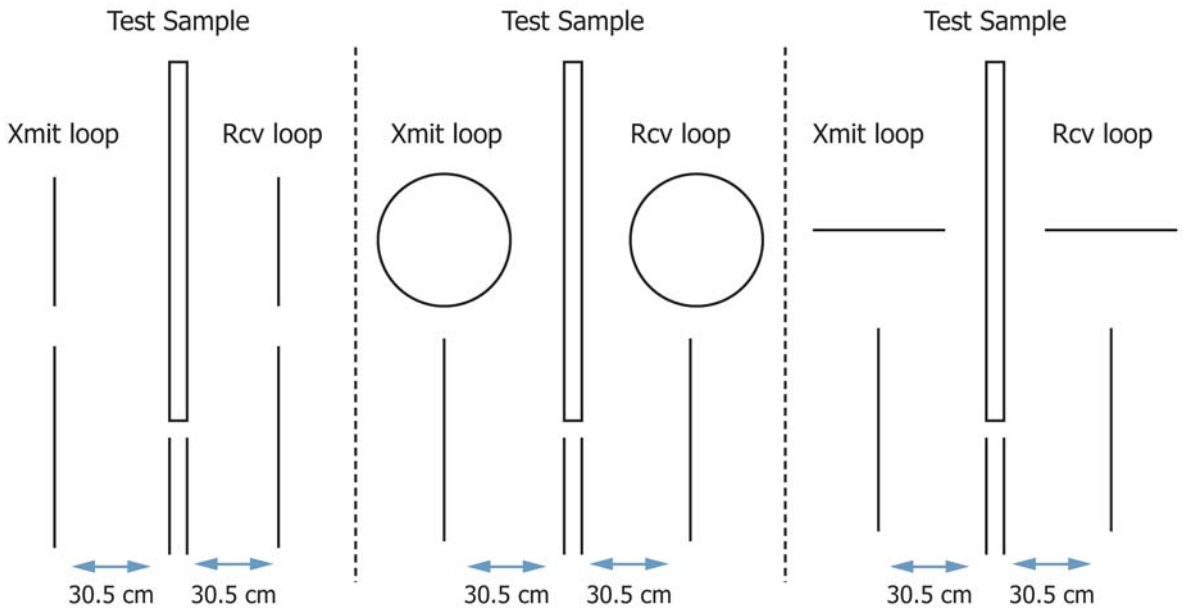

FIG. 1 Magnetic Field Antenna Positions

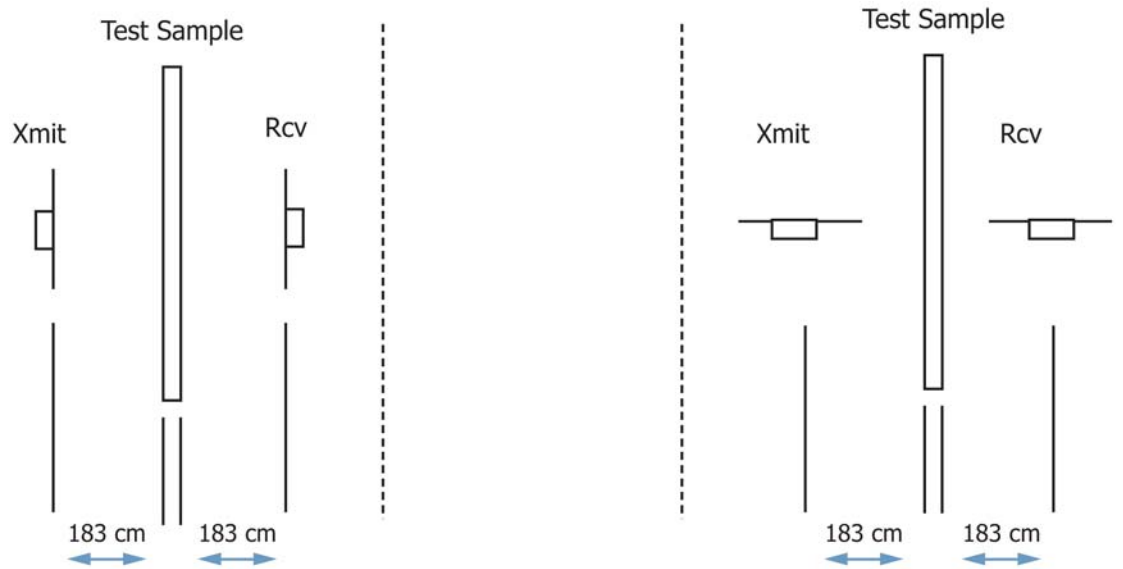

FIG. 2 Electric Field Antenna Positions (Dipoles and Monopoles)

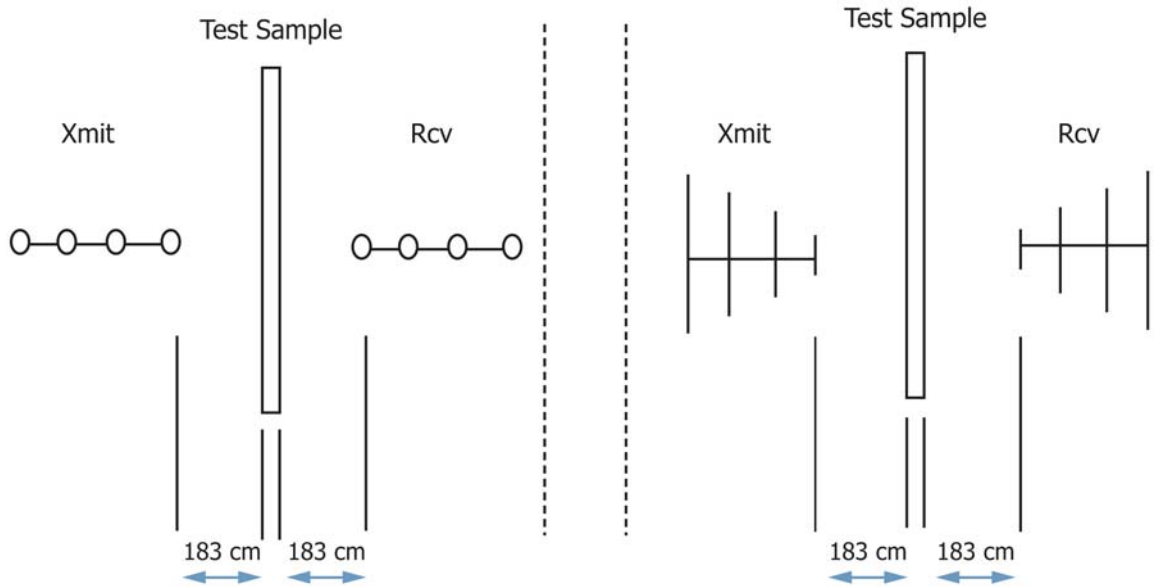

FIG. 3 Electric Field Antenna Positions (Log Periodic et al)

(3) Location of shielded enclosure test,
(4) Conditions restricting the performed measurements,
(5) Sketch of test set up with test points labeled, and
(6) Dates tests were performed.

15.3 *Measurement Procedure*—The measurement procedure shall be in accordance with this test method. Deviations from the standard procedure shall be noted, and explanations for the deviations shall be provided.

15.4 *Measurement Apparatus*—Measurement apparatus and antennas shall be identified by manufacturer, model, and serial number. Dates of latest calibration (traceable to the National Institute of Standards and Technology) shall be provided and shall not predate the measurements by more than one year.

15.5 *Glazing or Glazing Configuration Description*—This section of the report will clearly define the glazing or glazing configuration with the following details:
(1) Overall nominal thickness of the specimen(s),
(2) Nominal thickness of each glazing ply,
(3) Glazing or glazing configuration name, brand, type, and color,
(4) If applicable—Coating designation and surface of application,
(5) If applicable—Interlayer brand, type, nominal thickness,
(6) If applicable—Position of laminated unit in glazing configuration,
(7) If applicable—Insulating space nominal thickness,

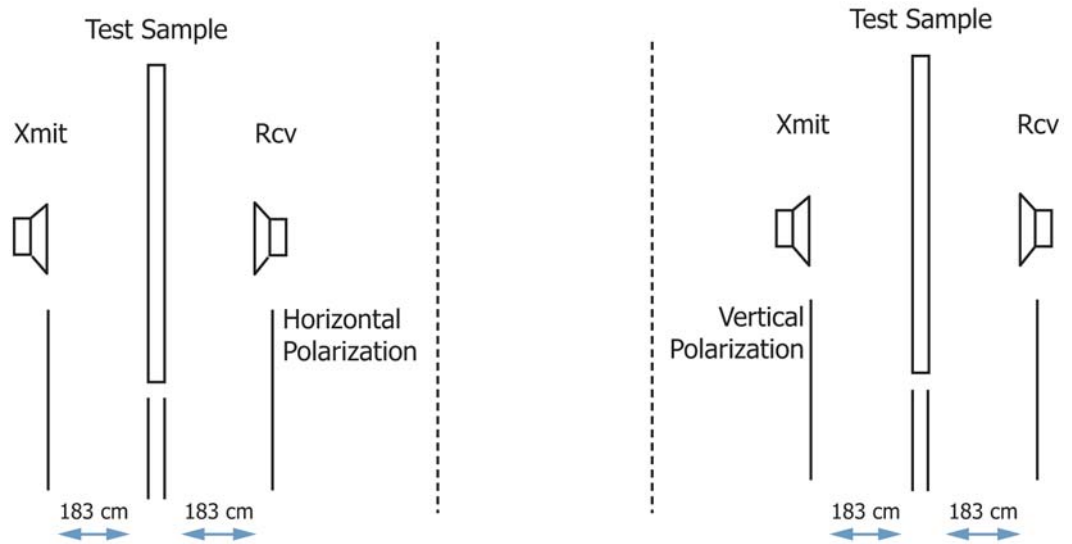

FIG. 4 Plane Wave Antenna Polarizations (Horns)

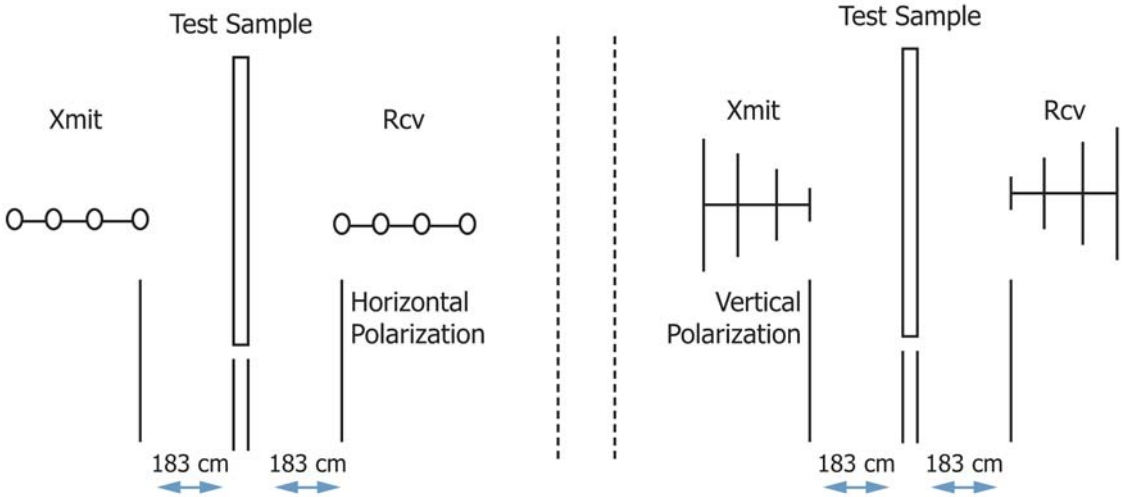

FIG. 5 Plane Wave Antenna Polarizations (Log Periodic et al)

(8) If applicable—Insulating spacer type, brand, and material, and

(9) If applicable—Film thickness, type, brand, and position in glazing configuration.

15.6 *Results:*

15.6.1 The end result must be a semi log plot with frequency on the log scale and attenuation on the linear scale. All raw data tables and plots shall also be provided.

15.6.2 Any format that provides the same information may be used. Summaries of data by test point or component may also be presented. In addition, include results, conclusions, and recommendations, as appropriate.

16. Precision and Bias

16.1 *Nonlinearity Effects*—Nonlinearity effects may be determined by placing source and receiving loops on opposite sides of a panel near its geometric center and measuring SE as a function of source strength. Generator strength is increased 10 dB in steps, nominally 0.1 to 1 and 10 W. If SE decreased more than 2 dB, perform intermediate level measurements. Plot the results to determine the highest level permissible for linear performance (within 61 dB).

16.2 *Cavity Resonances*—A measurement procedure is not recommended for frequencies in the range of the lowest cavity resonances, because considerable variability of data is found in this frequency range. The frequency range to be avoided is approximately 0.8 to 3 fr, where fr is the lowest cavity resonance frequency. For an enclosure of height *h m* and longest side *l m*, the lowest resonant frequency in MHz is approximately:

$$\text{fr } 5\ 150 = \sim 1/\text{h2!1} \sim 1/12!,\ \text{h, 1 (6)} \qquad (1)$$

16.3 Minimize signal reflections whenever possible.

16.4 It is not practicable to specify the precision of the procedure for measuring shielding effectiveness of a glazing or glazing configuration material because the test method measures relative numbers and the measured numbers usually vary a few decibels when repeated.

17. Keywords

17.1 coated glass; electromagnetic measurements; filmed glazing; glass; glazing; laminated glass; laminates; magnetic fields; plane waves; radio frequencies; shielding effectiveness

APPENDIX

(Nonmandatory Information)

X1. SELECTING MEASUREMENT FREQUENCIES

X1.1 Regulatory Note

X1.1.1 Transmitter operation must be authorized by the Federal Communications Commission (FCC). A special temporary authorization (STA) may be obtained on the basis of an existing experimental license (FCC Rules, Part 5, Paragraph 5.5.6). The STA may be obtained by letter, and the response time is usually less than 30 days. The STA is valid for 30 days of operation but allows adding new frequencies temporarily if needed for special tests.

X1.1.2 The licensed experimental equipment must be operated only under the supervision of an FCC commercial first or second class operator's license (either radiotelephone or radiotelegraph). If a licensed operator is not already a member of the testing staff, a staff member should obtain such an operator's license (see *Rules and Regulations of the FCC*, Vol 1, Part 13).

X1.2 Selecting Frequencies

X1.2.1 The Table of Frequency Allocations in the FCC Rules, Part 2, Paragraph 2.106 should be studied to select frequencies that are most likely to be approved. In general, frequencies will probably be approved where no interference to other licensed radio services is likely to occur. The length of time each frequency will be used should always be stated. If frequencies are to be used intermittently, they are more likely to be approved. Under intermittent use interference tends to be minimized, and the FCC may approve intermittent use of frequencies for which continuous use could not be approved. It is advisable to limit the request in the business, industrial, and petroleum radio-service frequencies.

X1.2.2 *Frequencies to Avoid*—In general, the Domestic Public radio Service frequencies should be avoided since this service is protected. Police and fire department frequencies should also be avoided.

X1.2.2.1 The exact frequency of a commercial broadcast station should be avoided if there is a reasonable chance that interference will occur.

X1.2.2.2 The following frequencies should not be requested: on or within the guard bands or any emergency frequencies in any of the VLF, LF, MF, or HF radio navigation channels active at or near the test locations. See FCC Rules, Part 2, Paragraph 2.106 for frequency allocations.

X1.2.2.3 Government frequencies should be avoided. Requesting government frequency or frequencies in the maritime service will slow down license processing. If government frequencies are needed, contact the local area frequency coordinator through the nearest military base communications officer. Early establishment of rapport with the area frequency coordinator is beneficial in any situation. If the coordinator is satisfied that no harmful interference to government services will occur, license authorization for government frequencies will be obtained.

X1.2.2.4 Standard frequencies such as WWV, Canadian time, and U.S. Naval Observatory should be avoided. The FCC cannot authorize their uses in experimental radio service. Radio-astronomy frequencies active in or near the service area should also be avoided. See FCC Rules, Part 2, Paragraph 2.106 for frequency allocations.

X1.2.2.5 All requests should be for discrete frequencies. A request for a band of frequencies should include a justification of why discrete frequencies cannot be used.

BIBLIOGRAPHY

(1) D1711 Standard Terminology Relating to Electrical Insulation
(2) D4935 Standard Test Method for Measuring the Electromagnetic Shielding Effectiveness of Planar Materials
(3) E1851 Standard Test Method for Electromagnetic Shielding Effectiveness of Durable Rigid Wall Relocatable Structures